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Modelling Economic Policy Issues

A full-fledged analytical model for the Laffer curve in personal income taxation☆

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ABSTRACT

The standard approach to evaluate the Laffer curve of personal income taxation focuses on the impact on income tax revenue alone. However, this is an incomplete depiction of reality, as income tax rate changes also affect revenue collection from other taxes -i.e. consumption taxes and social security contributions. In addition, to the extent that administration and compliance costs correlate with tax rates, the Laffer curve should also consider this correlation. This paper develops a complete microeconomic model for the Laffer curve of personal income tax, taking into account all these omissions. Results confirm that these omissions generate the false illusion of a Laffer curve with a higher-than-real revenue maximum and a narrower prohibitive zone than exists in reality.

1. Introduction

Tax revenue adequacy has always been one of the defining features of a healthy budgetary policy. Consequently, a broad spectrum of arguments has defended the need to achieve sufficient levels of tax collection. These arguments range from the gullible search for the "common good" by a benevolent and generous State to less naïve ones, such as the one defended by the School of Public Choice, in which the State's voracious appetite for tax revenue reflects not only the general interest but also the desire to satisfy the personal preferences of politicians and bureaucrats. Whatever the reason, the study of tax systems' revenue capacity has been and will continue to be one of the primary fiscal policy concerns. In this context, this paper analyses the controversial Laffer curve in the Personal Income Tax (PIT). The Laffer curve generates controversy because it appeals to the existence of limits to taxation, even when the intention is to maximise tax revenue. Its invocation, therefore, is usually interpreted as a call for budgetary restraint, which means that specific political options tend to classify it more as an instrument at the service of fiscal austerity than as a rigorous tool for economic analysis. To

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a large extent, this perception is responsible for the valuation of the Laffer curve being made more from the ideological sphere than from the neutrality of economic analysis.

Since Arthur B. Laffer drew his famous curve on a Washington restaurant's napkin in the mid-1970s, the existence of an inverse relationship between tax rates and revenue has occupied an important place in the tax debate. Far from the trivia of the napkin, the Laffer curve is one of the most studied and well-founded concepts of contemporary economic thought. However, surprisingly, the Laffer curve debate has been fought essentially in the political arena, feeding more on proclamations and opinions than on rigorous and reasoned analysis. This simplistic way of framing the discussion of the Laffer curve has divided the interested audience into two irreconcilable groups: those who defend the existence of the Laffer curve and those who deny it. The former we will call the credulous or "gullible" group and the latter the "denialists". Economic theory and most empirical evidence indicate the former as victors over the latter, confirming the Laffer curve's undeniable reality. However, the gullible victory is not complete because of the gullible mistake of identifying the existence of the Laffer curve with the taxpayer's forced location in the descending leg of that curve. In other words, although the denialists are categorically mistaken in denying the existence of the Laffer curve, the postulates of the gullible are not entirely correct and need to be nuanced.

As Arthur Laffer himself acknowledges, and as authors such as Wanniski (1978), Fullerton (1982) and Lindsey (1985) demonstrate, the idea of the existence of an inverse relationship between tax collection and rates does not owe its origin to Arthur Laffer. On the contrary, this relationship was noted much earlier by authors such as Hume (1756), Smith (1776) and Dupuit (1844), among others. However, after Arthur Laffer intervened in the debate, his ideas came to the fore and seized a preferential niche in tax design.[1]

Since the 1970s, much research has been done on the Laffer curve and the underlying economic ideas. The 1980s began with an explosion of more or less complex economic models that sought to quantify taxation's "Laffer effect". These initial models include those of Stuart (1981) and Feige and McGee (1985) for Swedish reality, and Fullerton (1982), Canto et al. (1983), Bender (1984) and Lindsey (1985) for the USA. With the emergence of behavioural economics, analysis of the Laffer phenomenon soon began to appear from this newly launched approach. Outstanding examples are the study by Swenson (1988) and the subsequent research by Sutter and Weck-Hannemann (2003). The first carried out an experiment to test whether taxes generate disincentives for labour supply, confirming the existence of the Laffer curve. The second reports a more sophisticated experiment in which the tax rate becomes endogenous from an interactive game of two players, one acting as a taxpayer (subject A) and the other as the tax authority (subject B). Sutter and Weck-Hannemann also confirm the existence of the Laffer curve experimentally.[2]

More recently, through a set of controlled experiments, Lévy-Garboua et al. (2009) postulate the existence of a new kind of Laffer curve, different from the conventional one, which they call the behavioural Laffer curve. This new curve arises as a punitive reaction to the perception of the injustice of taxes. It has the peculiarity of reaching the prohibitive zone significantly earlier than the conventional Laffer curve. In this same tradition, although with a different approach, Ortona et al. (2008) drew attention to an interesting fact: the use given to tax collection and the existence of excessive administration and compliance costs have a decisive impact on taxpayers' valuation of taxes. Therefore, States must be cautious in spending what they collect since waste induces a fall in the taxpayer's labour effort and a lower willingness to pay taxes, with the consequent decrease in the collection and the strengthening of the Laffer effect.

Other papers, grounded mostly in theory, have analysed the factors that reinforce or weaken this Laffer effect of taxation. Administrative bureaucracy, corruption and the black economy are some of the most significant elements. Forte (1987), for example, states that the existence of rent-seeking bureaucracy and administrative and compliance costs require us to distinguish between two different Laffer curves: one linked to gross revenue and the other with the net revenue of those costs. Forte concludes that the Laffer curve of net receipts is a left-hand translation of the Laffer curve of gross receipts, firstly because gross receipts and net receipts differ conceptually, and secondly because the indirect costs of taxation – administration and compliance costs – cause the gross receipts associated with any tax rate to be lower. Adopting the same line of reasoning, Sanyal et al. (2000) confirmed that, in a corrupt environment, increasing the tax effort required from taxpayers can lead to a loss of revenue, mainly if penalties and tax rates positively affect the level of corruption of the tax administration. Similarly, Panadés (2003) found that raising tax rates or tightening anti-fraud policies, besides being regressive, do not increase revenue when evasion costs are low. Moreover, Vogel (2012) confirms that the existence of the shadow economy reinforces the characteristic inverted U-shape of the Laffer curve for PIT and Corporation Tax (CT); however, he finds no such impact on consumption taxes.

Endogenous growth models have also led to a fruitful generation of Laffer curve studies. From this macroeconomic approach, tax revenue is analysed from a multi-temporal perspective, where the fiscal policy actions carried out in the present have consequences on the welfare and budgetary sustainability of the future. Such studies have coined the notion

[1] To a large extent, the ideas underlying the Laffer curve helped to generate the paradigm shift in the tax systems of the 1980s. Ronald Reagan's reforms in 1981 and 1986 and Margaret Thatcher's reform in 1984 were the first to be decisively inspired by this new pattern. These reforms were later imitated by other countries.

[2] In addition, Sutter and Weck-Hannemann analyse the impact of making decisions about work effort and tax rate under "*the veil of ignorance*". To this end, the results of two experiments are contrasted: one where the relative positions of the players – taxpayer or tax authority – are known from the beginning; another, under uncertainty, where the players do not know their respective roles until the end of the experiment. In this state of uncertainty (veil of ignorance), both players must decide on the tax rate and the level of effort they would be willing to exert. The results show that under the veil of ignorance, taxpayers tend to work harder and set lower tax rates — around 20% lower.

of the *dynamic Laffer curve*. This Laffer curve postulates that the expansionary effects associated with a reduction in tax rates in the present are, in general, strong enough to ensure an increase in social welfare and future tax bases, thus guaranteeing the financial sustainability of the Budget in the long term. Ireland (1994), Pecorino (1995), Novales and Ruiz (2002), Nutahara (2015), Oudheusden (2016) and Bosca et al. (2017) are outstanding examples of such studies. Under different assumptions, all these studies corroborate the existence of the dynamic Laffer curve in taxation levied on wages, capital and consumption.[3]

Finally, other authors have opted to model the Laffer curve analytically, which enables the analysis of the Laffer curve mathematically and gives the chance to model explicitly alternative income tax designs. Moreover, if adequate microdata is available, analytical models can be computed empirically for every individual taxpayer in the population. To the extent that tax microdata reliably represents the actual distribution of taxable incomes, this analytical approach is arguably the most reliable and robust method for deriving the Laffer curve, especially in the case of personal income taxation. References using this analytical approach include Giertz (2009), Saez et al. (2012), Creedy (2015), Creedy and Gemmell (2013, 2015) and Sanz-Sanz (2016a,b). However, although this analytical approach is possibly the most robust of all the existing techniques for analysing the Laffer curve, its implementation in the current literature suffers from a significant omission: analysis is restricted exclusively to the collection consequences on the PIT. In other words, the existing analytical models ignore that marginal tax rate changes also alter the revenue from other levies, such as taxes on consumption or Social Security contributions. Furthermore, current analytical models also overlook the fact that taxes impose additional burdens in the form of administrative and compliance costs that widen the gap between gross and net Laffer curves. This paper aims to fill all these gaps and develop a full-fledged PIT Laffer curve model. Computations are first performed for an individual taxpayer and then aggregated to obtain the expressions for the total population (aggregate Laffer Curve).

The paper is structured as follows. Section 2 presents the set-up in which the full-fledged model of the Laffer curve is developed, distinguishing between gross and net Laffer curves. In this section, we obtain the Laffer curve functions for PIT according to the revenue impacts taken into account. Specifically, the Laffer curve functions are obtained under different revenue settings: when only the revenue impact on personal income taxation is recorded, when the revenue from consumption taxes is added and when social security contributions are incorporated into the analysis. Finally, the Laffer curve net of administration and compliance costs is also derived. Based on these functions, Section 3 analyses the changes in the bill of an individual taxpayer, obtaining the so-called mechanical and behavioural effects, from which revenue-maximising rates and revenue-maximising elasticities are calculated. With these mathematical developments, the aggregate revenue from a population of taxpayers is modelled in Section 4. Section 5 offers a simulation exercise illustrating the consequences on the Laffer curve of missing out on commodity taxation, social security contributions, and administration and compliance costs. Finally, Section 6 concludes.

2. An extended analytical model for the Lafferffer curve of the PIT

As mentioned at the outset, the existing microeconomic models on the Laffer curve are incomplete, because they ignore many of the revenue effects resulting from altering the marginal PIT rates. For example, they fail to consider that changes in the marginal rate also modify the average rates of the taxpayer population and, therefore, they omit the changes in the collection of taxes levied on consumption. Likewise, social security contributions are deductible from the taxpayer's tax base, and consequently, the modification of the marginal tax rates in the PIT also alters the actual collection from social contributions. Finally, following Forte (1987), it should not be overlooked that taxes impose burdens also in terms of administration and compliance costs. The difference between gross and net Laffer curves will widen to the extent that these "hidden costs" of taxation correlate with the magnitude of the tax rates.

In sum, the existing analytical models in the literature on the Laffer curve of the PIT limit their analysis to the PIT's collection, ignoring the revenue implications on other taxes and levies, as well as on the administration and compliance costs. All these omissions must be considered, to have a more realistic picture of the Laffer effect of personal income taxation. The following sub-section defines an appropriate analytical framework for inserting all these ignored effects.

2.1. An extended set-up

Following Sanz-Sanz (2016b), we assume an economy that levies taxes on personal income as well as on consumption. In addition, labour income is levied with Social Security contributions, to cover contingencies such as retirement or sickness. Moreover, all these levies are costly in terms of administration and compliance. All these items operate according to the following scheme:

(1) Taxable income, y_i, is taxed by applying a tax schedule, $\zeta = \zeta(\vec{\tau}, \vec{A})$, characterised by a vector of increasing marginal tax rates $\vec{\tau} = (\tau_0, \tau_1, \ldots, \tau_k)$ and a set of sequential income thresholds $\vec{A} = (a_0, a_1, \ldots, a_k)$ – i.e. the relevant income tax function is $T_{y_i} = T_Y(y_i, \zeta)$.

[3] The Laffer curve of excise taxes has been the subject of monographic analysis in Aasness and Nygård (2014) and Guedes de Oliveira and Costa (2015). While the first study evaluates for Norway the Laffer curve of taxes levied on tobacco and alcoholic beverages, the second calculates, from the estimation of a quadratic collection function, the Laffer curve of VAT for 27 countries that make up the current European Union (EU). More recently, Miravete et al. (2018) have characterised the Laffer curve robustly in retail sales taxation of alcoholic beverages in noncompetitive markets.

(2) T_{c_i} is the consumption tax function, defined on disposable income, $V_i = y_i - T_{y_i}$, according to a set of tax-inclusive rates, $\vec{\varsigma} = (t_1, t_2, \ldots, t_q)$, levied on the Q categories of goods and services exchanged in the economy. Vector $\vec{\varsigma}$ includes VAT rates and excises. So that if the taxpayer's total consumption, C_i, is distributed among the Q goods and services according to weights $w_{q_i} = \frac{C_{q_i}}{C_i}$, where $\sum_{q=1}^{Q} w_{q_i} = 1$, the taxpayer's effective tax rate on consumption is $\alpha_i = \chi_i \cdot \sum_{q=1}^{Q} w_{q_i} \cdot t_q$, where χ_i represents the (marginal) taxpayer's propensity to consume.

(3) As part of the total taxable income, any working taxpayer, i, will have gross taxable earnings y_{w_i} equal to $y_{w_i} = w_i \cdot h_i$, where w_i is the gross hourly wage of the individual and h_i his hours of work. These gross earnings will also face the social security contributions (SSC) on the part of the employee.[4] As a consequence, this new levy will generate an additional revenue equal to

$$T^{w}_{ss_i} = \bar{t}^{ss}_{w_i} \cdot (1 - \sigma \cdot \tau_{k_i}) \cdot y_{w_i} \tag{1}$$

where $\bar{t}^{ss}_{w}$ represents the average Social Security tax rate of the employee and σ the proportion of the employee's contribution that is deductible from his taxable income.

(4) Paying taxes is a costly activity in itself, giving rise to administration and compliance costs (ACC). A critical difference between these two types of costs is that while the taxpayer privately absorbs the former, the latter is charged to total collected revenue. Although compliance costs are borne privately, they can affect tax revenue by exerting a negative impact on the supply of taxable income. Therefore, to the extent that y_i is affected by the magnitude of the compliance costs, these costs will reduce not only the net tax revenue, but also the gross tax revenue associated with any tax rate. Although there is little evidence about the actual shape of the compliance and administration cost functions, it seems sensible to regard both as an increasing and convex function of the marginal tax rates -i.e. $\frac{dACC}{d\tau} > 0$ and $\frac{d^2ACC}{d\tau^2} > 0$.

From this analytical framework, collected in (1)–(4), we can define the gross Laffer curve of an individual taxpayer, T_{g_i}, as the sum of his PIT, consumption and Social Security tax functions:

$$T_{g_i} = T_{y_i} + T_{c_i} + T^{w}_{ss_i} \tag{2}$$

By subtracting from this gross Laffer curve the administration and compliance costs of the individual taxpayer, T_{ψ_i}, we obtain the taxpayer's net Laffer curve:

$$T_{n_i} = T_{g_i} - T_{\psi_i} \tag{3}$$

2.2. The gross Laffer curve of an individual taxpayer in this extended framework

Assuming a global income tax based on the notion of extensive income, the income tax burden associated with income y_i of an individual taxpayer i will be as follows:

$$T(y_i) \begin{cases} \tau_1 \cdot (y_i - a_1) & \textit{if} \quad a_1 < y_i \leq a_2 \\ \tau_1 \cdot (a_2 - a_1) + \tau_2 \cdot (y_i - a_2) & \textit{if} \quad a_2 < y_i \leq a_3 \\ \tau_1 \cdot (a_2 - a_1) + \tau_2 \cdot (a_3 - a_2) + \tau_3 \cdot (y_i - a_3) & \textit{if} \quad a_3 < y_i \leq a_4 \\ \ldots & \quad \ldots \\ \ldots & \quad \ldots \\ \tau_1 \cdot (a_2 - a_1) + \cdots \tau_{K-1} \cdot (a_{K-2} - a_{K-1}) + \tau_K \cdot (y_i - a_K) & \textit{if} \quad y_i > a_K \end{cases}$$

which, replicating Creedy and Gemmell (2006), can be rewritten in a compact format as:

$$T_{y_i} = \tau_{k_i} \cdot \left[y_i - a'_{k_i} \right] \tag{4}$$

where τ_{k_i} is the top marginal rate associated with y_i and a'_{k_i} denotes the *effective threshold* defined as $a'_k = \frac{1}{\tau_{k_i}} \cdot \sum_{j=1}^{K} a_j \cdot (\tau_j - \tau_{j-1})$.

Concerning consumption tax revenue, as consumption emerges from disposable income (after PIT), T_{c_i} can be written as:

$$T_{c_i} = \chi_i \cdot \left[y_i - T_{y_i} \right] \cdot \sum_{q=1}^{Q} w_{q_i} \cdot t_q \tag{5}$$

which after substituting (4) into (5) and rearranging terms, becomes:

$$T_{c_i} = \alpha_i \cdot \left[y_i \cdot \left(1 - \tau_{k_i}\right) + \tau_{k_i} \cdot a'_{k_i} \right] \tag{6}$$

[4] We assume no tax shifting in SSC — i.e. statutory incidence equals economic incidence.

Table 1
Alternative individual gross Laffer curves depending on which taxes are considered.

Income tax only
$T_{y_i} = \tau_{k_i} \cdot (y_i - a'_{k_i})$
Income tax + consumption taxes
$T_{(y+c)_i} = \tau_{k_i} \cdot \left[y_i \cdot \left(1 + \frac{(1-\tau_{k_i})}{\tau_{k_i}} \cdot \alpha_i \right) - a'_{k_i} \cdot (1-\alpha_i) \right]$
Income tax + consumption taxes + social security contributions
$T_{g_i} = \tau_{k_i} \cdot \left[y_i \cdot \left(1 + \frac{(1-\tau_{k_i})}{\tau_{k_i}} \cdot \alpha_i + \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot \frac{1-\sigma \cdot \tau_{k_i}}{\tau_{k_i}} \right) - a'_{k_i} \cdot (1-\alpha_i) \right]$
where: $a'_{k_i} = \sum_{j=1}^{k} a_j \cdot \left(\frac{\tau_j - \tau_{j-1}}{\tau_{ki}} \right)$

Therefore, under this setting, an individual taxpayer – with incomes y_i and y_{w_i}, such that $y_{w_i} \leq y_i$, and total consumption C_i – will generate gross total tax revenue, T_{g_i}, equal to:

$$T_{g_i} = T_{y_i} + T_{c_i} + T^{w}_{ss_i} \tag{7}$$

which can be written more compactly, by taking into account Eqs. (1), (4) and (6), as:

$$T_{g_i} = \tau_{k_i} \cdot \left(y_i - a'_{k_i} \right) \cdot (1-\alpha_i) + \left[\alpha_i + \bar{t}^{ss}_{w_i} \cdot (1 - \sigma \cdot \tau_{k_i}) \cdot \theta_i \right] \cdot y_i \tag{8}$$

where $\theta_i = \frac{y_{w_i}}{y_i}$.

Eq. (8) is the correct tax function to consider the gross revenue implications derived from changes in marginal tax rates. However, welfare and revenue implications of income tax rate changes are usually analysed focusing only on income taxation, i.e. using T_{y_i}. As a result, most of the existing empirical and theoretical work derives from the "abridged" version of reality represented by (4), instead of the more accurate picture depicted by (8).

Table 1 exhibits, in an easily comparable format, the three alternative Laffer curve functions depending on the taxes considered in the model. The first is used in standard analysis, where only the PIT is considered. The second takes consumption tax revenue into consideration (see Sanz-Sanz (2016b)) and the third is the extended tax function (8) which, by adding SSC, embraces the whole revenue implications of PIT tax rate changes in comprehensive income taxes.

From the equations in Table 1, it can be inferred that for an individual taxpayer, the gross Laffer curve can be characterised as:

$$T_{g_i} = \tau_{k_i} \cdot \left(A \cdot y_i - B \cdot a'_{k_i} \right) \tag{9}$$

which is a generalisation of the PIT function reported by Creedy and Gemmell (2006). Depending on coefficients A and B, (9) opens the possibility of taking into account, together with the PIT, other taxes and levies affected by the magnitude of PIT rates. To be specific, if only income tax is considered, then $A = B = 1$, and (9) reproduces Creedy and Gemmell's formula. When income and consumption taxes are taken into account together, then $A = \left(1 + \frac{(1-\tau_{k_i})}{\tau_{k_i}} \cdot \alpha_i \right)$ and $B = (1-\alpha_i)$. Finally, by making allowance for Social Security Contributions together with income and consumption taxes, it turns out that $A = \left(1 + \frac{(1-\tau_{k_i})}{\tau_{k_i}} \cdot \alpha_i + \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot \frac{1-\sigma \cdot \tau_{k_i}}{\tau_{k_i}} \right)$ whereas B remains as $B = (1-\alpha_i)$.

2.3. The net Laffer curve: the relevant tax function in the presence of administration and compliance costs

Eq. (8) depicts the extended (individual) gross Laffer curve, which, however, overlooks the existence of administration and compliance costs. Therefore, the net Laffer curve can be determined by subtracting the revenue consequences of the administration and compliance costs on the tax bill of the taxpayer, T_{ψ_i}:

$$T_{n_i} = T_{y_i} + T_{c_i} + T^{w}_{ss_i} - T_{\psi_i} \tag{10}$$

Quantifying and ensuring payment of a tax give rise to administration and compliance costs. However, most studies on the Laffer curve, either theoretical or empirical, have ignored this fact. To the best of my knowledge, the only exception to this omission is Forte (1987), who distinguishes between gross and net Laffer curves by including the operating costs of taxation into the analysis. In the context of the Laffer curve, a fundamental conceptual difference between administration and compliance costs is that while the taxpayers privately absorb the former, the latter uses the revenue raised from taxpayers and consequently reduces the disposable tax revenue for public use. As a result, as Forte posited, this loss of tax revenue due to administration and compliance costs should be made explicit in analysing the Laffer curve. As highlighted

by Shaw et al. (2010), the structure of tax rates and the ease with which the tax base can be concealed is particularly relevant for administration costs. In this respect, as far as personal income tax is concerned, high administration costs can be inferred. Likewise, to the extent that high tax rates may make taxpayers more prone to tax evasion and tax avoidance, administration costs can be expected to be positively correlated with the size of marginal tax rates. Although there is little evidence about the actual shape of the administration cost function, for the reasons mentioned above, it seems sensible to regard them as an increasing and convex function of the marginal tax rates -i.e. $\frac{dAC}{d\tau} > 0$ and $\frac{d^2AC}{d\tau^2} > 0$.[5]

Together with the administration costs, the (net) Laffer curve also requires to account for compliance costs. As mentioned above, this other concealed burden of taxation is borne by taxpayers privately. However, as noted by Forte (1987), it can affect tax collection as it exerts a negative impact on the supply of taxable income. Therefore, to the extent that y_i is affected by the magnitude of the compliance costs; these costs will reduce not only the net tax revenue but also the gross tax revenue associated with any tax rate. We will assume an exponential cost function for both.

For administration costs (AC):

$$AC_i(\overline{\tau}_i) = A_0^i \cdot e^{a \cdot \overline{\tau}_i} \tag{11}$$

where A_0^i identifies the initial *per capita* administration cost necessary to start the operation of the tax system, while a is the factor at which the individual administration cost varies in the face of changes in the (average) marginal rate of the taxpayer, $\overline{\tau}_i$, when one or more of the marginal rates of the tax schedule are changed. Specifically, the average marginal rate of a given individual taxpayer will be determined by:

$$\overline{\tau}_i = \sum_{j=0}^{k-1} \frac{a_{j+1} - a_j}{y_i} \cdot \tau_j + \frac{y_i - a_k}{y_i} \cdot \tau_k \tag{12}$$

As in the case of administration costs, the compliance costs borne individually, C_i, will describe an exponential trajectory equal to:

$$C_i(\overline{\tau}_i) = C_0^i \cdot e^{b \cdot \overline{\tau}_i} \tag{13}$$

where C_0^i represents the initial compliance cost of taxpayer i and b captures the expansion factor in the face of changes in his (average) marginal tax rate, $\overline{\tau}_i$. This private compliance cost, $C_i(\tau_i)$, generates collective compliance costs in the form of revenue loss associated with the reduction in the reported taxable income, due to the compliance costs borne privately. In this way, the full compliance cost of an individual taxpayer will be given by the sum of two components:

$$CC_i\left(\overline{\tau}_i\right) = C_i\left(\overline{\tau}_i\right) + T_i(y_i(C_i\left(\overline{\tau}_i\right))) \tag{14}$$

The first right-hand term represents the taxpayer's private compliance cost. In contrast, the second quantifies the reduction in the individual tax bill associated with the reduction in the reported taxable income due to those compliance costs. Whereas the former component has no impact on the Laffer curve, as the taxpayer privately pays it, the latter component does have an impact, as it erodes the revenue power of the tax. The mechanism to reduce tax collection is produced through the effect of compliance costs on the magnitude of the reported taxable income. Therefore, the revenue effect of the administration and compliance costs will be:

$$T_{\psi_i} = AC\left(\overline{\tau}_i\right) + T_i(y_i(C_i\left(\overline{\tau}_i\right))) \tag{15}$$

Consequently, taking into account (10) and (11), the net Laffer curve will be given by:

$$T_{n_i} = \tau_{k_i} \cdot \left(A \cdot y_i - B \cdot a'_{k_i}\right) - A_0 \cdot e^{a \cdot \overline{\tau}_i} - T_i(y_i(C_i\left(\overline{\tau}_i\right))) \tag{16}$$

3. The individual (gross) tax bill and the change in the marginal tax rates

3.1. Rate changes and the gross tax bill of an individual taxpayer

Given the general tax function (9), an alteration in any tax rate $\tau_h : \tau_h \in \zeta = \zeta(\vec{\tau}, \vec{A})$, will induce a change in the tax bill of the individual taxpayer, T_{g_i}, equals:

$$\frac{dT_{g_i}}{d\tau_h} = \frac{\tau_{k_i}}{\tau_h} \cdot A \cdot y_i \cdot \left(\eta_{\tau_{ki},\tau_h} + \eta_{A,\tau_h} + \eta_{y_i,\tau_h}\right) - \frac{\tau_{k_i}}{\tau_h} \cdot B \cdot a'_{k_i} \cdot \left(\eta_{\tau_{ki},\tau_h} + \eta_{B,\tau_h} + \eta_{a'_{ki},\tau_h}\right) \tag{17}$$

which, depending on the relative position of τ_h to the taxpayer's marginal rate, τ_{k_i}, will work out to be:

$$\frac{dT_{g_i}}{d\tau_h} \begin{cases} \frac{\tau_{k_i}}{\tau_h} \cdot A \cdot y_i \cdot \left(\eta_{A,\tau_h} + \eta_{y_i,\tau_h}\right) - \frac{\tau_{k_i}}{\tau_h} \cdot B \cdot a'_{k_i} \cdot \left(\eta_{B,\tau_h} + \eta_{a'_{ki},\tau_h}\right) & if \quad \tau_h < \tau_{k_i} \\ A \cdot y_i \cdot \left(1 + \eta_{A,\tau_{k_i}} + \eta_{y_i,\tau_{k_i}}\right) - B \cdot a'_{k_i} \cdot \left(1 + \eta_{B,\tau_{k_i}} + \eta_{a'_{ki},\tau_{k_i}}\right) & if \quad \tau_h = \tau_{k_i} \\ 0 & if \quad \tau_h > \tau_{k_i} \end{cases} \tag{18}$$

[5] As Forte (1987) indicates, it can be argued that with positive administration costs at close to zero, marginal administration costs may grow less than proportionally at subsequent low rates, whereas at higher rates, they may grow more than proportionally.

The equations in (18) capture the general form of the marginal effect on the gross tax due caused by a change in the rates of a multi-rate tax schedule. As can be seen, this marginal effect depends on A and B — i.e. on the type and number of taxes incorporated in the modelling of the Laffer curve. Depending on A and B, this marginal effect can be particularised as follows:

• $A = B = 1$ (income tax only)

$$\frac{dT_{g_i}}{d\tau_h} \begin{cases} (a_{h+1} - a_h) & if \quad \tau_h < \tau_{k_i} \\ y_i \cdot \left(1 + \eta_{y_i,\tau_{k_i}}\right) - a_k & if \quad \tau_h = \tau_{k_i} \\ 0 & if \quad \tau_h > \tau_{k_i} \end{cases} \tag{19}$$

• $A = \left(1 + \frac{1-\tau_{k_i}}{\tau_{k_i}} \cdot \alpha_i\right)$; $B = (1 - \alpha_i)$ (income tax + taxes on consumption)

$$\frac{dT_{g_i}}{d\tau_h} \begin{cases} \frac{\tau_{k_i}}{\tau_h} \cdot \eta_{\alpha_i,\tau_h} \cdot \alpha_i \cdot \left(y_i \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}} + a'_{k_i}\right) + (1 - \alpha_i) \cdot (a_{h+1} - a_h) & if \quad \tau_h < \tau_{k_i} \\ y_i \cdot \left(1 + \eta_{y_i,\tau_{k_i}}\right) - a_k + \frac{d\alpha_i}{d\tau_{k_i}} \cdot \left[y_i - \tau_{k_i} \cdot \left(y_i - a'_{k_i}\right)\right] & \\ \quad -\alpha_i \cdot \left[y_i \cdot \left(1 - \eta_{y_i,\tau_{k_i}} \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}}\right) - a_k\right] & if \quad \tau_h = \tau_{k_i} \\ 0 & if \quad \tau_h > \tau_{k_i} \end{cases} \tag{20}$$

• $A = \left(1 + \frac{\left(1-\tau_{k_i}\right)}{\tau_{k_i}} \cdot \alpha_i + \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot \frac{1-\sigma\cdot\tau_{k_i}}{\tau_{k_i}}\right)$; $B = (1 - \alpha_i)$ (income tax + taxes on consumption + SS contributions)

$$\frac{dT_{g_i}}{d\tau_h} \begin{cases} \frac{\tau_{k_i}}{\tau_h} \cdot \eta_{\alpha_i,\tau_h} \cdot \alpha_i \cdot \left(y_i \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}} + a'_{k_i}\right) + (1 - \alpha_i) \cdot (a_{h+1} - a_h) & \\ -\bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i & if \quad \tau_h < \tau_{k_i} \\ y_i \cdot \left(1 + \eta_{y_i,\tau_{k_i}}\right) - a_k + \frac{d\alpha_i}{d\tau_{k_i}} \cdot \left[y_i - \tau_{k_i} \cdot \left(y_i - a'_{k_i}\right)\right] & \\ -\alpha_i \cdot \left[y_i \cdot \left(1 - \eta_{y_i,\tau_{k_i}} \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}}\right) - a_k\right] & \\ -\bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i \cdot \left(\eta_{\bar{t}^{ss}_{w_i},(1-\tau_{ki})} + \eta_{y_{wi},(1-\tau_{ki})}\right) & if \quad \tau_h = \tau_{k_i} \\ 0 & if \quad \tau_h > \tau_{k_i} \end{cases} \tag{21}$$

3.1.1. The mechanical and behavioural effects

As suggested by the existing literature, in the face of a change in marginal rates, the tax bill of an individual taxpayer will be altered through two alternative channels: the mechanical effect (ME) and the behavioural effect (BE). The former captures the revenue change with no behavioural reaction of the taxpayer -i.e. the pure arithmetical revenue change. The latter, conversely, provides a measure of the variation in the tax payment due to the taxpayer's behavioural response. The two effects move in opposite directions and together dictate the actual change in the tax bill of the taxpayer. Sanz-Sanz (2016a) highlighted that the computation of *ME* and *BE* at an individual level allows a full characterisation of the Laffer curve individually and place each taxpayer on his/her particular Laffer curve. To be specific, if $ME > BE$ the taxpayer is located in the rising section of his Laffer curve, whereas if the contrary applies and $ME < BE$, the taxpayer would be placed in the decreasing or "prohibitive" section of his Laffer curve. Needless to add, the knowledge of the precise location of the taxpayers within their own personal Laffer curves is vital to infer the actual revenue impact of a given rate change. As the first-order condition of the revenue maximisation problem, $\frac{dT_{g_i}}{d\tau_h} = 0$, is met at $ME = BE$; revenue-maximising tax rates, τ^L, may also be computed by solving for τ in the equalisation of *ME* and *BE*. The analytical relevance of ME and BE is further reinforced if we bear in mind that they are *first-order* approximations to some relevant money metrics. As highlighted by Giertz (2009), the variation in the Excess Burden is approximated by BE, whereas ME roughly quantifies the *Hicksian* Equivalent Variation.

From the equations reported in (19)–(21), the magnitude of ME and BE will differ, depending on A and B. It is hence crucial to model the Laffer curve correctly and fully. If we leave out of the modelling the impact of a rate change on any of the affected tax structures – income tax, consumption taxes or the Social Security contributions – we will be ignoring the relevant effects of the rate change under scrutiny and, therefore, will probably be prescribing incorrect policy actions. Mechanical and behavioural effects are computed below to depict this, depending on the taxes incorporated in the modelling of the Laffer curve.

Starting from (19)–(21), rearranging terms and taking into account that $\eta_{y_i,\tau_{ki}} = -\frac{\tau_{ki}}{1-\tau_{ki}} \cdot \eta_{y_i,(1-\tau_{ki})}$ it is possible to isolate the mechanical and behavioural effects associated with any given rate change. Focussing the analysis when $\tau_h = \tau_{k_i}$, if we only account for the effects on the revenue of the personal income tax, a modification in τ_{k_i} will result in a revenue

change equal to:

$$\frac{dT_i}{d\tau_{ki}} = \underbrace{(y_i - a_k)}_{\text{ME}} - \underbrace{y_i \cdot \frac{\tau_{ki}}{1-\tau_{ki}} \cdot \eta_{y_i,(1-\tau_{ki})}}_{\text{BE}} \tag{22}$$

where $\eta_{y_i,(1-\tau_{ki})}$ is the so-called taxable income elasticity popularised by Feldstein (1995, 1999) and a_k represents the nominal threshold of bracket k in the tax schedule. As shown, the first bracketed term on the right-hand side of (22) captures *ME*, whereas the second term is *BE*. Notwithstanding this, when income and consumption taxes are taken into account together, the tax bill change becomes:

$$\frac{dT_i}{d\tau_{ki}} = \underbrace{\underbrace{(y_i - a_k)\cdot(1-\alpha_i)}_{\text{ME}} - \underbrace{y_i \cdot \frac{\tau_{ki}}{1-\tau_{ki}} \cdot \eta_{y_i,(1-\tau_{ki})}}_{\text{BE Income tax}} - \underbrace{\alpha_i \cdot \left[\eta_{y_i,(1-\tau_{ki})} \cdot y_i + \eta_{\alpha_i,(1-\tau_{ki})} \cdot \left(y_i + \frac{\tau_{ki} \cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]}_{\text{BE Consumption taxes}}}_{\text{BE Total}} \tag{23}$$

where α_i is the average tax rate on taxpayer's consumption and $\eta_{\alpha_i,(1-\tau_{ki})}$ denotes the elasticity of α_i to the net-of-income-tax rate. As can be seen, when consumption taxes appear on the scene, both *ME* and *BE* are different from the ones reported in (22). Additionally, if we account for SSC, the tax bill change as a whole is

$$\frac{dT_i}{d\tau_{ki}} = \underbrace{(y_i - a_k)\cdot(1-\alpha_i) - \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i}_{\text{ME}}$$

$$\underbrace{-y_i \cdot \frac{\tau_{ki}}{1-\tau_{ki}} \cdot \eta_{y_i,(1-\tau_{ki})}}_{\text{BE Income tax}} \underbrace{- \alpha_i \cdot \left[\eta_{y_i,(1-\tau_{ki})} \cdot y_i + \eta_{\alpha_i,(1-\tau_{ki})} \cdot \left(y_i + \frac{\tau_{ki} \cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]}_{\text{BE Consumption taxes}}$$

$$\underbrace{-\bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i \cdot \left(\eta_{\bar{t}^{ss}_{w_i},(1-\tau_{ki})} + \eta_{y_{wi},(1-\tau_{ki})}\right)}_{\text{BE Social Security Contributions}} \tag{24}$$

BE Total

where behavioural reactions affecting collection of SSC are encapsulated in $\eta_{\bar{t}^{ss}_{w_i},(1-\tau_{ki})}$ and $\eta_{y_{wi},(1-\tau_{ki})}$. The former is the elasticity of the employee's average SSC tax rate to the net-of-income-tax rate and the latter, the elasticity of the employee's taxable income from labour.

Table 2 reports the biases caused in the mechanical and behavioural effects of a change in τ_h, when $\tau_h = \tau_{k_i}$, due to the failure to consider consumption taxes and SSC in the modelling. These biases caused the miscalculation of the actual Laffer curve for personal income taxation, which has significant implications for the revenue forecast and welfare.

Together with this, if the rate change occurs in a bracket lower than the one in which the taxpayer's taxable income falls – i.e. $\tau_h < \tau_{k_i}$ – taxpayer's average rate will be altered even though his marginal rate remains intact. As reported in Eqs. (19)–(21), this change in the average tax rate will cause a mechanical effect in the PIT, as well as a behavioural

Table 2
Overestimation in *ME* and *BE* caused by omitting the impact of PIT marginal tax rates on consumption tax revenue and SSC — for changes in τ_h when $\tau_h = \tau_{k_i}$.

Omission	Excess in *ME*	Excess in *BE*
Consumption tax Revenue	$\alpha_i \cdot (y_i - a_k)$	$\alpha_i \cdot \left[\eta_{y_i,(1-\tau_{ki})} \cdot y_i + \eta_{\alpha_i,(1-\tau_{ki})} \cdot \left(y_i + \frac{\tau_{ki} \cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]$
Consumption tax Revenue + SSC	$\alpha_i \cdot (y_i - a_k) + \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i$	$\alpha_i \cdot \left[\eta_{y_i,(1-\tau_{ki})} \cdot y_i + \eta_{\alpha_i,(1-\tau_{ki})} \cdot \left(y_i + \frac{\tau_{ki} \cdot a'_{k_i}}{1-\tau_{ki}}\right)\right] + \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i \cdot \left(\eta_{\bar{t}^{ss}_{w_i},(1-\tau_{ki})} + \eta_{y_{wi},(1-\tau_{ki})}\right)$

Table 3
Overestimation in *ME* and *BE* caused by omitting the impact of PIT marginal tax rates on consumption tax revenue and SSC — for changes in τ_h when $\tau_h < \tau_{k_i}$.

Omission	Excess in *ME*	Excess in *BE*
Consumption tax Revenue	$\alpha_i \cdot (a_{h+1} - a_h)$	$\frac{\tau_{k_i}}{\tau_h} \cdot \eta_{\alpha_i,\tau_h} \cdot \alpha_i \cdot \left(y_i \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}} + a'_{k_i}\right)$
Consumption tax Revenue + SSC	$\alpha_i \cdot (a_{h+1} - a_h)$	$\frac{\tau_{k_i}}{\tau_h} \cdot \eta_{\alpha_i,\tau_h} \cdot \alpha_i \cdot \left(y_i \cdot \frac{1-\tau_{k_i}}{\tau_{k_i}} + a'_{k_i}\right)$

effect on commodity taxation. Table 3 shows the bias in the calculation of these mechanical and behavioural effects due to the omission of commodity taxation and social security contributions in the modelling of the Laffer curve, when the rate change is in inner tax brackets.

3.1.2. The revenue-maximising rates

As we have just seen, not considering consumption taxes and/or social security contributions has consequences for the magnitude of mechanical and behavioural effects. One of the implications of these biases is the distortion in the magnitude of the revenue-maximising rates. If the modelling of the Laffer curve reckons only the revenue on the personal income tax itself, the revenue-maximising rate, τ^L will be given by the following expression:

$$\tau^L_I = \frac{(y_i - a_k)}{\left[y_i \cdot \eta_{y_i,(1-\tau_{k_i})} + (y_i - a_k)\right]} \tag{25}$$

whereas if consumption taxes are incorporated, τ^L reaches:

$$\tau^L_{I+C} = \frac{(y_i - a_k) \cdot (1-\alpha_i) - \alpha_i \cdot y_i \cdot \left(\eta_{y_i,(1-\tau_{k_i})} + \eta_{\alpha_i,(1-\tau_{k_i})}\right)}{(y_i - a_k) \cdot (1-\alpha_i) - \alpha_i \cdot y_i \cdot \left(\frac{\alpha_i - 1}{\alpha_i} \cdot \eta_{y_i,(1-\tau_{k_i})} + \frac{tme}{\tau_{k_i}} \cdot \eta_{\alpha_i,(1-\tau_{k_i})}\right)} \tag{26}$$

Further, if Social Security contributions are added to the model, the revenue-maximising rate will be determined by:

$$\tau^L_{I+C+SSC} = \frac{(y_i - a_k) \cdot (1-\alpha_i) - \alpha_i \cdot y_i \cdot \left(\eta_{y_i,\left(1-\tau_{k_i}\right)} + \eta_{\alpha_i,\left(1-\tau_{k_i}\right)}\right) - \varphi}{(y_i - a_k) \cdot (1-\alpha_i) - \alpha_i \cdot y_i \cdot \left(\frac{\alpha_i - 1}{\alpha_i} \cdot \eta_{y_i,(1-\tau_{k_i})} + \frac{tme}{\tau_{k_i}} \cdot \eta_{\alpha_i,(1-\tau_{k_i})}\right) - \varphi} \tag{27}$$

donde $\varphi = \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i \cdot \left(1 + \eta_{\bar{t}^{ss}_{w_i},(1-\tau_{ki})} + \eta_{y_{wi},(1-\tau_{ki})}\right)$

3.1.3. The revenue-maximising elasticities

As pointed out by Fullerton (1982), the two fundamental parameters in the debate on the Laffer curve are the marginal rates and the taxable income elasticity. The emphasis on the disincentive effects associated with marginal rates is explained only in terms of the magnitude of the taxable income elasticity. If this elasticity is high enough, even low marginal rates could cause the taxpayer to be in the prohibitive zone of his Laffer curve. Conversely, if the elasticity is low enough, even with high marginal rates, the taxpayer could be in the normal zone of his Laffer curve. In other words, the taxpayer's location in the *revenue-rate* space -i.e. Laffer curve — depends decisively on the magnitude of the taxable income elasticity. Following this reasoning, Fullerton (1982) suggests a new curve, where the emphasis is placed on the taxable income elasticity. Specifically, Fullerton proposes drawing a "modified Laffer curve" which, instead of relating marginal rates and revenue, delimits the combination of rates and elasticities that ensure revenue maximisation. This new curve, which we call *Fullerton curve* after its proponent, identifies the marginal rate that maximises revenue for a given elasticity. As outlined in Fig. 1, the combination of rates and elasticities to the southwest of the curve signifies

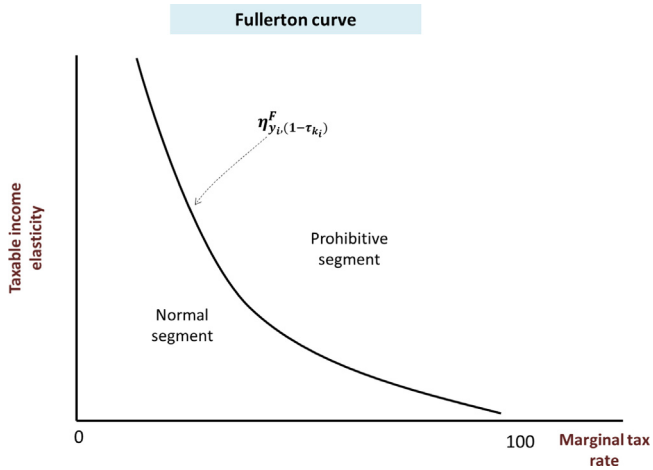

Fig. 1. Illustration of a Fullerton curve identifying revenue-maximizing tax rates for alternative taxable income elasticities.

the "normal zone", while the points to the northeast identify the combinations of rates and elasticities falling into the prohibitive area of the Laffer curve.

Therefore, the Fullerton curve identifies the boundary value of the elasticity separating the normal and the prohibitive zones of the Laffer curve. Fullerton curves are also affected by the number and type of taxes incorporated in the modelling. In particular, if only the PIT revenue is considered, the functional form of the Fullerton curve will be:

$$\eta_I^F = \frac{(y_i - a_k) \cdot \left(1 - \tau_{k_i}\right)}{y_i \cdot \tau_{ki}} \tag{28}$$

If we incorporate consumption taxes, the Fullerton curve becomes the following:

$$\eta_{I+C}^F = \frac{(y_i - a_k) \cdot (1 - \alpha_i) - \alpha_i \cdot \eta_{\alpha_i,\left(1-\tau_{k_i}\right)} \cdot \left[y_i - \frac{\tau_{ki}}{1-\tau_{ki}} \cdot a'_{k_i}\right]}{y_i \left[\frac{\tau_{ki}}{1-\tau_{ki}} + \alpha_i\right]} \tag{29}$$

Finally, if we also consider the impact on social security contributions, it will take the form in (30).

$$\eta_{I+C+SSC}^F = \frac{(y_i - a_k) \cdot (1 - \alpha_i) - \alpha_i \cdot \eta_{\alpha_i,\left(1-\tau_{k_i}\right)} \cdot \left[y_i - \frac{\tau_{ki}}{1-\tau_{ki}} \cdot a'_{k_i}\right] - \varphi}{y_i \left[\frac{\tau_{ki}}{1-\tau_{ki}} + \alpha_i\right]} \tag{30}$$

3.2. The effect of administration and compliance costs: The net Laffer curve

Do compliance and administration costs affect the collection capacity of marginal tax rates in personal income taxation? As already mentioned in Section 2.3, the answer is affirmative, and it does so in two ways. First, to the extent that marginal rates modify the *per capita* administration costs of the tax system, $AC\ (\overline{\tau}_i)$ and second, to the extent that the marginal rate affects the magnitude of the reported taxable income through the effect of the marginal rate on taxpayer's compliance costs, $T_i(y_i(C_i\ (\overline{\tau}_i)))$, i.e. administration and compliance costs affect the Laffer curve profile to the extent that rate changes affect function (14), replicated here below:

$$T_{\psi_i} = AC\ (\overline{\tau}_i) + T_i(y_i(C_i\ (\overline{\tau}_i)))$$

This fact implies that the expressions presented in the preceding section should incorporate the effects of the change in τ_h on T_{ψ_i}, summarised as follows — see Appendix:

$$\frac{dT_{\psi_i}}{d\tau_h} \begin{cases} A_0^i \cdot a \cdot e^{b\cdot\overline{\tau}_i} \cdot \frac{(a_{h+1}-a_h)}{y_i} + \tau_k \cdot \eta_{y_i,C_i} \cdot b \cdot (a_{h+1} - a_h) & if \quad \tau_h < \tau_{k_i} \\ A_0^i \cdot a \cdot e^{b\cdot\overline{\tau}_i} \cdot \frac{(y_i-a_k)}{y_i} + \tau_k \cdot \eta_{y_i,C_i} \cdot b \cdot (y_i - a_k) & if \quad \tau_h = \tau_{k_i} \end{cases} \tag{31}$$

where η_{y_i,C_i} quantifies the elasticity of the taxpayer's reported taxable income to his/her compliance costs. It is essential to note that when modelling the Laffer curve, compliance costs are considered only to the extent that they affect the magnitude of the reported taxable income, not the compliance cost itself. It is to be noted that while the first summands in

(31) quantify the mechanical effect associated with the change in the *per capita* administrative costs, the second summands calculate something like a behavioural effect of those compliance costs that translates into a lower tax bill, due to the reduction in the reported taxable income.

4. Changes in aggregate revenue

From the perspective of fiscal policy, the impact of rate changes on tax revenue is more relevant if it is analysed for the entire population of taxpayers. Thus, based on the preceding individual microeconomic model, we compute the effect of rate changes on total revenue for a population of N taxpayers. In the context of heterogeneous taxpayers, this individual tax bill aggregation requires detailed knowledge of the distributions of tax units and taxable incomes in the population. Analytical expressions for the aggregate revenue and the characterisation of the aggregate Laffer curve are provided below.

4.1. Aggregate revenue change and marginal tax rates

We start from the individual net Laffer curve captured in Eq. (16), customised to include all taxes involved – income tax, consumption tax and social contributions – as well as administration and compliance costs:

$$T_{n_i} = \tau_{k_i} \cdot \left(y_i - a'_{k_i}\right) \cdot (1-\alpha_i) + \left[\alpha_i + \bar{t}^{ss}_{w_i} \cdot \left(1 - \sigma \cdot \tau_{k_i}\right) \cdot \theta_i\right] \cdot y_i - \left[A^i_0 \cdot e^{a \cdot \bar{\tau}_i} + T_i(y_i(C_i(\bar{\tau}_i)))\right] \tag{32}$$

From this function and taking into account the analytical expressions (22)–(24) y (31), an individual taxpayer would be subject to the mechanical and behavioural effects summarised in Table 4. As can be seen, these mechanical and behavioural effects depend on the relative position of τ_{k_i} to the modified tax rate, τ_h, as well as on the taxes we consider in the modelling.

4.2. Aggregation over the whole population

If our interest is to quantify the aggregate revenue impact of a change in τ_h on a finite population of N filers, the expressions in Table 4 indicate the necessity to discriminate the total population of taxpayers according to their location within the tax schedule. Therefore, in the analytical developments that follow, N_h will identify the number of taxpayers for whom $\tau_{k_i} = \tau_h$ whereas N^+_h will collect the number of taxpayers to whom it happens that $\tau_{k_i} > \tau_h$. Besides, as N^0_h denotes the number of taxpayers with $\tau_{k_i} < \tau_h$, they are not affected in any way by the rate change. Therefore, $N = N^0_h + N_h + N^+_h$.

Due to the large number of effects to consider, in the calculation of the aggregate revenue change, we will compute the aggregate mechanical and behavioural impact separately.

4.2.1. The aggregate mechanical effects

The mechanical effects contained in Table 4 are aggregated for a population of N taxpayers. This aggregate mechanical effect across the whole population, ME_N, is computed as follows:

$$ME_N = \sum_{N^+_h} (1-\alpha_i) \cdot (a_{h+1} - a_h) - \sum_{N^+_h} A^i_0 \cdot a \cdot e^{b \cdot \bar{\tau}_i} \cdot \frac{(a_{h+1} - a_h)}{y_i} + \sum_{N_h} (y_i - a_k) \cdot (1-\alpha_i) - \sum_{N_h} \bar{t}^{ss}_{w_i} \cdot \theta_i \cdot y_i - \sum_{N_h} A^i_0 \cdot a \cdot e^{b \cdot \bar{\tau}_i} \cdot \frac{(y_i - a_k)}{y_i} \tag{33}$$

that gives:

$$ME_N = N^+_h \cdot (a_{h+1} - a_h) \cdot \left[\left(1 - \bar{\alpha}^+_h\right) - A^i_0 \cdot a \cdot \frac{\left(\overline{e^{b \cdot \bar{\tau}_i}}\right)^+_h}{\bar{y}^+_h}\right] + N_h \cdot \left[(\bar{y}_h - a_h) \cdot (1 - \bar{\alpha}_h) - \left(\bar{t}^{ss}_{w_i}\right)_h \cdot \bar{\theta}_h \cdot \bar{y}_h - A^i_0 \cdot a \cdot \left(\overline{e^{b \cdot \bar{\tau}_i}}\right)_h \cdot \frac{(\bar{y}_h - a_h)}{\bar{y}_h}\right] \tag{34}$$

where the bar indicates the mean value of the corresponding parameter. A barred parameter combined simultaneously with a subscript h and a superscript $+$ indicates that the mean is calculated over the taxpayers for whom $\tau_h < \tau_k$, while if the barred parameter has only a subscript h, the mean is computed for taxpayers whose income falls within bracket h — i.e. for whom $\tau_{k_i} = \tau_h$. For example, $\bar{\alpha}^+_h$ indicates the mean effective tax rate on consumption for taxpayers falling into tax brackets above h, whereas α_h denotes the average of the same tax rate, but computed over taxpayers falling within bracket h. It is worth noting that the first addend in (34) collects the outside mechanical effects, whereas the second captures the within mechanical effects — see Sanz-Sanz (2016a).

Table 4
Mechanical and behavioural effects on an individual taxpayer, depending on the relative position of τ_{k_i} to τ_h and the taxes taken into account.[a]

Taxes and levies considered	$\tau_h < \tau_{k_i}$	
	MECHANICAL EFFECTS	BEHAVIOURAL EFFECTS
PIT only	$(a_{h+1} - a_h)$	–––––
PIT + CT	$(1-\alpha_i)\cdot(a_{h+1}-a_h)$	$\frac{\tau_{k_i}}{\tau_h}\cdot\eta_{\alpha_i,\tau_h}\cdot\alpha_i\cdot\left(y_i\cdot\frac{1-\tau_{k_i}}{\tau_{k_i}}+a'_{k_i}\right)$
PIT + CT + SS	$(1-\alpha_i)\cdot(a_{h+1}-a_h)$	$\frac{\tau_{k_i}}{\tau_h}\cdot\eta_{\alpha_i,\tau_h}\cdot\alpha_i\cdot\left(y_i\cdot\frac{1-\tau_{k_i}}{\tau_{k_i}}+a'_{k_i}\right)$
PIT + CT+ SS + ACC	$(1-\alpha_i)\cdot(a_{h+1}-a_h)-A_0^i\cdot a\cdot e^{b\cdot\overline{\tau}_i}\cdot\frac{(a_{h+1}-a_h)}{y_i}$	$\frac{\tau_{k_i}}{\tau_h}\cdot\eta_{\alpha_i,\tau_h}\cdot\alpha_i\cdot\left(y_i\cdot\frac{1-\tau_{k_i}}{\tau_{k_i}}+a'_{k_i}\right)-\tau_k\cdot\eta_{y_i,C_i}\cdot b\cdot(a_{h+1}-a_h)$
Taxes and levies considered	$\boldsymbol{\tau_h = \tau_{k_i}}$	
	MECHANICAL EFFECTS	BEHAVIOURAL EFFECTS
PIT only	$(y_i - a_k)$	$-y_i\cdot\frac{\tau_{ki}}{1-\tau_{ki}}\cdot\eta_{y_i,(1-\tau_{ki})}$
PIT + CT	$(y_i-a_k)\cdot(1-\alpha_i)$	$-y_i\cdot\frac{\tau_{ki}}{1-\tau_{ki}}\cdot\eta_{y_i,(1-\tau_{ki})}-\alpha_i\cdot\left[\eta_{y_i,(1-\tau_{ki})}\cdot y_i+\eta_{\alpha_i,(1-\tau_{ki})}\cdot\left(y_i+\frac{\tau_{ki}\cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]$
PIT + CT + SS	$(y_i-a_k)\cdot(1-\alpha_i)-\overline{t}^{ss}_{w_i}\cdot\theta_i\cdot y_i$	$-y_i\cdot\frac{\tau_{ki}}{1-\tau_{ki}}\cdot\eta_{y_i,(1-\tau_{ki})}-\alpha_i\cdot\left[\eta_{y_i,(1-\tau_{ki})}\cdot y_i+\eta_{\alpha_i,(1-\tau_{ki})}\cdot\left(y_i+\frac{\tau_{ki}\cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]$ $-\overline{t}^{ss}_{w_i}\cdot\theta_i\cdot y_i\cdot\left(\eta_{\overline{t}^{ss}_{w_i},(1-\tau_{ki})}+\eta_{y_{wi},(1-\tau_{ki})}\right)$
PIT + CT+ SS + ACC	$(y_i-a_k)\cdot(1-\alpha_i)-\overline{t}^{ss}_{w_i}\cdot\theta_i\cdot y_i-A_0^i\cdot a\cdot e^{b\cdot\overline{\tau}_i}\cdot\frac{(y_i-a_k)}{y_i}$	$-y_i\cdot\frac{\tau_{ki}}{1-\tau_{ki}}\cdot\eta_{y_i,(1-\tau_{ki})}-\alpha_i\cdot\left[\eta_{y_i,(1-\tau_{ki})}\cdot y_i+\eta_{\alpha_i,(1-\tau_{ki})}\cdot\left(y_i+\frac{\tau_{ki}\cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]$ $-\overline{t}^{ss}_{w_i}\cdot\theta_i\cdot y_i\cdot\left(\eta_{\overline{t}^{ss}_{w_i},(1-\tau_{ki})}+\eta_{y_{wi},(1-\tau_{ki})}\right)-\tau_k\cdot\eta_{y_i,C_i}\cdot b\cdot(y_i-a_k)$

[a]Meaning of the acronyms: PIT = Personal Income Tax; TC = Taxes on consumption; SS = Social Security Contributions; ACC = Administration and Compliance Costs

4.2.2. The aggregate behavioural effects

The aggregate behavioural effect across the whole population, BE_N, is computed below:

$$\begin{aligned}BE_N = &\sum_{N_h^+}\frac{\tau_{k_i}}{\tau_h}\cdot\eta_{\alpha_i,\tau_h}\cdot\alpha_i\cdot\left(y_i\cdot\frac{1-\tau_{k_i}}{\tau_{k_i}}+a'_{k_i}\right)-\sum_{N_h^+}\tau_k\cdot\eta_{y_i,C_i}\cdot b\cdot(a_{h+1}-a_h)\\ &-\sum_{N_h}y_i\cdot\frac{\tau_{ki}}{1-\tau_{ki}}\cdot\eta_{y_i,(1-\tau_{ki})}-\sum_{N_h}\alpha_i\cdot\left[\eta_{y_i,(1-\tau_{ki})}\cdot y_i+\eta_{\alpha_i,(1-\tau_{ki})}\cdot\left(y_i+\frac{\tau_{ki}\cdot a'_{k_i}}{1-\tau_{ki}}\right)\right]\\ &-\sum_{N_h}\overline{t}^{ss}_{w_i}\cdot\theta_i\cdot y_i\cdot\left(\eta_{\overline{t}^{ss}_{w_i},(1-\tau_{ki})}+\eta_{y_{wi},(1-\tau_{ki})}\right)-\sum_{N_h}\tau_{k_i}\cdot\eta_{y_i,C_i}\cdot b\cdot(y_i-a_k)\end{aligned}\tag{35}$$

which gives:

$$\begin{aligned}BE_N = &N_h^+\cdot\left\{\frac{\left(\overline{\tau}_{k_i}\right)_h^+}{\tau_h}\cdot\left(\overline{\eta}_{\alpha,\tau_h}\right)_h^+\cdot\overline{\alpha}_h^+\cdot\left(\overline{y}_h^+\cdot\frac{1-\left(\overline{\tau}_{k_i}\right)_h^+}{\left(\overline{\tau}_{k_i}\right)_h^+}+\left(\overline{a}'_{k_i}\right)_h^+\right)+\left(\overline{\tau}_{k_i}\right)_h^+\cdot\left(\overline{\eta}_{y_i,C_i}\right)_h^+\cdot b\cdot(a_{h+1}-a_h)\right\}\\ &-N_h\cdot\overline{y}_h\cdot\frac{\left(\overline{\tau}_{k_i}\right)_h}{1-\left(\overline{\tau}_{k_i}\right)_h}\cdot\left(\overline{\eta}_{y_i,(1-\tau_{ki})}\right)_h\\ &-N_h\cdot\overline{\alpha}_h\cdot\left[\left(\overline{\eta}_{y_i,(1-\tau_{ki})}\right)_h\cdot\overline{y}_h+\left(\overline{\eta}_{\alpha_i,(1-\tau_{ki})}\right)_h\cdot\left(\overline{y}_h+\frac{\left(\overline{\tau}_{k_i}\right)_h}{1-\left(\overline{\tau}_{k_i}\right)_h}\cdot\left(\overline{a}'_{k_i}\right)_h\right)\right]\\ &-N_h\cdot\left(\overline{\overline{t}^{ss}_{w_i}}\right)_h\cdot\overline{\theta}_h\cdot\overline{y}_h\cdot\left[\left(\overline{\eta}_{\overline{t}^{ss}_{w_i},(1-\tau_{ki})}\right)_h+\left(\overline{\eta}_{y_{wi},(1-\tau_{ki})}\right)_h\right]\\ &-N_h\cdot\left(\overline{\tau}_{k_i}\right)_h\cdot\left(\overline{\eta}_{y_i,C_i}\right)_h\cdot b\cdot(\overline{y}_h-a_h)\end{aligned}$$

Therefore, given a change in τ_h, the expected shift in tax collection for a population of N taxpayers will be given by:

$$dT = (ME_N + BE_N)\cdot d\tau_h\tag{36}$$

Table 5
Change in aggregate tax revenue for a population of size N depending on the taxes considered.[a]

PITonly	$dT = \left\{\left[(a_{h+1} - a_h) \cdot N_h^+ + (\bar{y}_h - a_h) \cdot N_h\right] - \frac{\tau_h}{1-\tau_h} \cdot \bar{\eta}^h_{y_i,(1-\tau_h)} \cdot N_h \cdot \bar{y}_h\right\} \cdot d\tau_h$
PIT + CT	$dT = \left\{\left[(a_{h+1} - a_h) \cdot \left(1 - \bar{\alpha}_h^+\right) \cdot N_h^+ + (\bar{y}_h - a_h) \cdot (1 - \bar{\alpha}_h) \cdot N_h\right] - \frac{N_h^+ \cdot \bar{\eta}^h_{\alpha_i,(1-\tau_h)} \cdot \bar{\alpha}_h^+ \cdot \bar{y}_h^+ \cdot \left(1-tme_h^+\right)}{\tau_h} - N_h \cdot \left[\frac{\tau_h}{1-\tau_h} \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} \cdot \bar{y}_h + \bar{\alpha}_h \cdot a'_h\right) + \bar{y}_h \cdot \bar{\alpha}_h \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} + \bar{\eta}^h_{\alpha_i,(1-\tau_h)}\right)\right]\right\} \cdot d\tau_h$
PIT + CT + SS	$dT = \left\{\left[(a_{h+1} - a_h) \cdot \left(1 - \bar{\alpha}_h^+\right) \cdot N_h^+ + (\bar{y}_h - a_h) \cdot (1 - \bar{\alpha}_h) \cdot N_h - \bar{t}^{ss}_{w_h} \cdot \bar{\theta}_h \cdot N_h \cdot \bar{y}_h\right] - \frac{N_h^+ \cdot \bar{\eta}^h_{\alpha_i,(1-\tau_h)} \cdot \bar{\alpha}_h^+ \cdot \bar{y}_h^+ \cdot \left(1-tme_h^+\right)}{\tau_h} - \bar{t}^{ss}_{w_h} \cdot \bar{\theta}_h \cdot \left(\bar{\eta}^h_{t^{ss}_w,(1-\tau_h)} + \bar{\eta}^h_{y_{w_i},(1-\tau_h)}\right) \cdot N_h \cdot \bar{y}_h - N_h \cdot \left[\frac{\tau_h}{1-\tau_h} \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} \cdot \bar{y}_h + \bar{\alpha}_h \cdot a'_h\right) + \bar{y}_h \cdot \bar{\alpha}_h \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} + \bar{\eta}^h_{\alpha_i,(1-\tau_h)}\right)\right]\right\} \cdot d\tau_h$
PIT + CT + SS + ACC	$dT = \left\{\left[(a_{h+1} - a_h) \cdot \left(1 - \bar{\alpha}_h^+\right) \cdot N_h^+ + (\bar{y}_h - a_h) \cdot (1 - \bar{\alpha}_h) \cdot N_h - \bar{t}^{ss}_{w_h} \cdot \bar{\theta}_h \cdot N_h \cdot \bar{y}_h\right] - a \cdot A_0^i \cdot \left[N_h^+ \cdot e^{b \cdot \bar{\tau}_h^+} \cdot \frac{(a_{h+1}-a_h)}{\bar{y}_h^+} + N_h \cdot e^{b \cdot \bar{\tau}_h} \cdot \frac{(\bar{y}_h - a_h)}{\bar{y}_h}\right] - \frac{N_h^+ \cdot \bar{\eta}^h_{\alpha_i,(1-\tau_h)} \cdot \bar{\alpha}_h^+ \cdot \bar{y}_h^+ \cdot \left(1-tme_h^+\right)}{\tau_h} - \bar{t}^{ss}_{w_h} \cdot \bar{\theta}_h \cdot \left(\bar{\eta}^h_{t^{ss}_w,(1-\tau_h)} + \bar{\eta}^h_{y_{w_i},(1-\tau_h)}\right) \cdot N_h \cdot \bar{y}_h - N_h \cdot \left[\frac{\tau_h}{1-\tau_h} \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} \cdot \bar{y}_h + \bar{\alpha}_h \cdot a'_h\right) + \bar{y}_h \cdot \bar{\alpha}_h \cdot \left(\bar{\eta}^h_{y_i,(1-\tau_h)} + \bar{\eta}^h_{\alpha_i,(1-\tau_h)}\right)\right] - b \cdot \left[N_h^+ \cdot \overline{\tau_{k_i}}_h^+ \cdot \overline{\eta_{y_i c_i}}_h^+ \cdot (a_{h+1} - a_h) + N_h \cdot \tau_h \cdot \overline{\eta_{y_i c_i}}_h \cdot (\bar{y}_h - a_k)\right]\right\} \cdot d\tau_h$

[a]Meaning of the acronyms: PIT = Personal Income Tax; TC = Taxes on consumption; SS = Social Security Contributions; ACC = Administration and Compliance Costs.

Table 6
Parameters used in the simulation.[a]

Behavioural parameters		Other parameters	
$\eta_{y_i,(1-\tau_{ki})} = 0.6$	$\bar{\eta}_{t^{ss}_{w_i},(1-\tau_{ki})} = 0$	$\alpha_i = 0.1125$	$\theta_i = 0.8$
$\bar{\eta}^h_{y_{w_i},(1-\tau_h)} = 0.45$	$\eta_{\alpha_i,(1-\tau_{ki})} = 0.05$	$t^{ss}_{w_i} = 0.06$	$A_0^i = 1000$
$\eta_{y_i,c_i} = -0.2$		$a = 0.1$	$b = 0.1$

[a]Behavioural elasticities correspond to the average values estimated for Spain — see Arrazola and de Hevia (2017). The consumption tax rate is the average value borne by household consumption in Spain calculated for 2018. Parameters defining the administration and compliance cost functions are approximate.

Table 5 summarises the explicit forms of function (36) depending on the taxes and costs considered in the analysis. As can be seen, the accurate modelling of the Laffer curve due to changes in marginal tax rates in income tax schedules requires consideration of consumption taxes, social security contributions and administration and compliance costs. Otherwise, catastrophic consequences will occur in revenue projections, and the actual aggregate profile of the Laffer curve will not be captured.

5. An illustrative simulation

This final section illustrates how the Laffer curve of an individual taxpayer varies depending on whether or not consumption taxes, social security contributions and administration and compliance costs are considered, when defining the profile of the Laffer curve. Ideally, the empirical application of the models presented above would be on real microdata of the current Spanish fiscal system. However, this exercise would require individualised information concerning personal income taxation, social contributions and taxes on consumption in a single database. Moreover, the administration costs per capita and the individualised private compliance costs for each taxpayer would also be required. Unfortunately, in Spain, a micro-database pooling such amount of precise information is not available; we hence carry out an illustrative exercise applying the functions presented above to a virtual (average) taxpayer. This exercise is sufficient to illustrate the consequences that can be expected by disregarding the impact that income tax rates exert on the revenue of consumption taxes and social contributions, as well as on administration and compliance costs.

Table 6 reports the parameter values used in the simulation, which roughly replicate those of the average Spanish taxpayer. With these parameter values, we will simulate an infinitesimal increase of the marginal rate ($d\tau = 0.001$) under the assumption that the tax base is governed entirely by a single marginal rate — i.e. $a_h = 0$ and $a_{h+1} = \infty$. This clarification is necessary, because most of the papers on the Laffer curve assume this same premise. However, they usually do not make it explicit despite being an assumption that is critical to describe the profile of the Laffer curve as well as for determining the magnitude of the tax rate that maximises revenue. However, despite this highly restrictive assumption of levying a single rate for the entire tax base, it helps us to understand the need for a full-fledged Laffer curve.

As Fig. 2 shows, ignoring consumption taxes, social security contributions and administration and compliance costs in assessing the effects of PIT rates does have significant implications on the ability to capture the actual Laffer curve. The consequences can be summarised as follows:

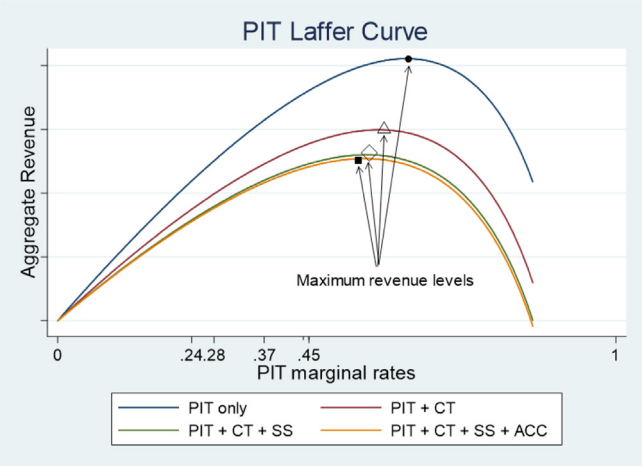

Fig. 2. Impact on the profile of the Laffer curve resulting from ignoring the implications of personal income tax rates on the revenue collection from other taxes (simulation results).

Table 7
PIT tax schedule for 2018 in Spain.[a]

K	a_K	τ_K	a'_K
1	0	0.19	0
2	12,450	0.24	2,593.75
3	20,200	0.3	6,115
4	35,200	0.37	11,617.568
5	60,000	0.45	20,218.889

[a]This tax schedule assumes that all the Autonomous Communities of the Common Regime replicate the State tax band.

a.-PIT rates systematically generate lower tax revenues when taxes other than the personal income tax are not considered. This misrepresentation of total revenue is especially evident in the intermediate tax rates, less evident for very low or very high rates.

b.-The underestimation of revenue is especially relevant when consumption taxes are ignored and, to a lesser extent, when disregarding social security contributions and administration and compliance costs.

c.-Not counting the effects on the revenue of other taxes is equivalent to a shift to the left of the actual Laffer curve, i.e. the normal zone of the actual Laffer curve is shrunk, whereas the prohibitive zone is expanded. To wit, actual revenue-maximising rates are lower than those prescribed by personal income tax revenue alone.

Fig. 3, which depicts the Fullerton curves simulated with the same data, confirms the conclusions noted in the three preceding points. Ignoring the effect of the marginal rates of personal income taxation on the collection of other taxes generates the illusion of a prohibitive zone less extensive than it is in reality. It can thus raise the false illusion of operating in the normal zone of the Laffer curve when, in reality, we would be located in the prohibitive zone of the real Laffer curve.

However, despite the illuminating analysis presented above, we should not forget that the traditional income taxes in most countries tend to have a step-wise rate structure. In other words, the total tax base is segmented into income brackets that face increasing marginal rates. This fact is usually not taken into account in most of the existing literature on the Laffer curve, and it was also not taken into account in the previous figures and simulations. Therefore, an interesting question is whether this type of design, widely applied in most tax systems, can affect the profile of the Laffer curve. In other words, can a step-wise design of the income tax alter the profile of the Laffer curve? To answer this question, we will replicate the above simulations under such a tax design, using the tax schedule applied in Spain in 2018, shown in Table 7.

In the new simulations, we will assume the same marginal rate increase as before – ($d\tau = 0.001$) – but on this occasion when the increased marginal rate exceeds the marginal rate separating each tax-bracket, we will consider that a new threshold applies. This means that the new marginal rate will affect only the amount of the tax base that is above this new threshold. The rest of the taxable income will be levied by previous tax rates. This fact will necessarily have a substantial effect on the magnitude of the collection gain associated with the marginal rate increases, as well as on the profile of the Laffer curve.

Fig. 4 illustrates the Laffer curves derived from the new simulations run on this more realistic assumption of multi-rate tax schedules. As shown in the right-hand panel of Fig. 4, the existence of multi-rate tax schedules significantly limits the collection capacity of marginal rate increases, since they apply not to the taxpayer's entire income, but only to a fraction

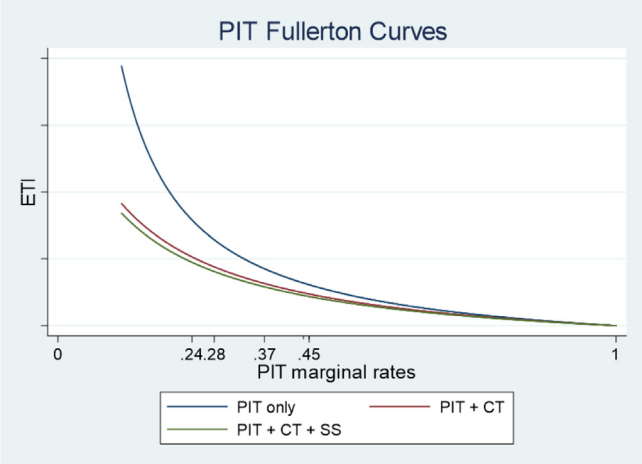

Fig. 3. Impact on the profile of the Fullerton curve resulting from ignoring the implications of personal income tax rates on the revenue collection from other taxes (simulation results).

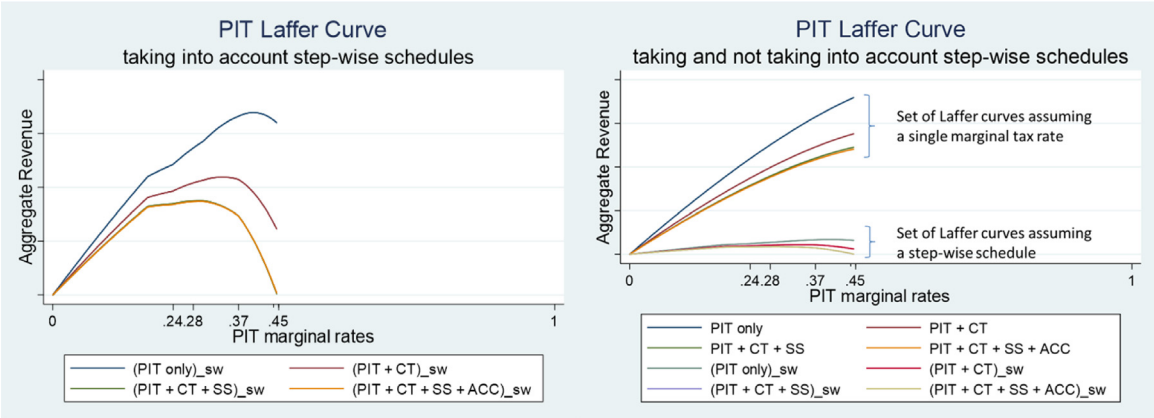

Fig. 4. Laffer curves under step-wise schedules compared to linear schedules (single tax rate).

Table 8
Revenue-maximising rates under a linear PIT versus a step-wise PIT.
—brackets of the Spanish PIT tax schedule for 2018—

	pit_only	pit+c	pit+c+ss	pit+c+ss+acc
linear	0.6250	0.5750	0.5530	0.5500
step-wise	0.4000	0.3280	0.2810	0.2820

thereof. Consequently, any rate increase will yield less revenue than under the alternative assumption of a single tax rate, which is the "hidden" assumption of most empirical work in the existing literature.

On the other hand, the left-hand panel of Fig. 4 indicates that the Laffer curves under a multi-rate tax schedule are much narrower than suggested by the (usually hidden) assumption of a single rate. As a result, the prohibitive zone is reached earlier and at much lower marginal rates. The revenue-maximising rates and revenue-maximising elasticities, reported in Tables 8 and 9, confirm this result.

6. Conclusions

In this paper, the Laffer curve of personal income taxation has been explored analytically in detail, and an extended microeconomic model has been proposed. The common denominator of the existing literature on this topic is to infer the Laffer curve, paying attention exclusively to the effects of PIT rates on the revenue of the personal income tax itself. This analytical approach constitutes a critical drawback that affects the profile of the Laffer curve, as PIT marginal rates, apart from affecting the collection of personal income taxation, also affect the revenue collection of other taxes and levies. Specifically, we identify two levies that should be incorporated in the discussion of the Laffer curve of the PIT:

Table 9
Revenue-maximising rates and revenue-maximising elasticities for each income bracket of the Spanish PIT tax schedule for 2018.

Revenue-maximising rates τ^L				Revenue-maximising elasticities $\eta^L_{y_i,(1-\tau_{ki})}$		
K	pit_only	pit+c	pit+c+ss	pit_only	pit+c	pit+c+ss
1	0.6250	0.5758	0.5538	9.5820	4.0665	3.7456
2	0.3900	0.3080	0.2477	1.4050	0.8690	0.6885
3	0.4153	0.3367	0.2815	1.1521	0.7731	0.6288
4	0.4079	0.3282	0.2716	0.8187	0.5859	0.4732
5	0.4000	0.3192	0.2610	0.1835	0.1535	0.1231

consumption taxes and social security contributions. The former omission ignored the fact that PIT marginal rates also alter the taxpayer's average tax rate and consequently, the actual revenue from consumption taxes. In so far as social security contributions are deductible from the tax base, the latter omission overlooks the implications on revenue collected from social security contributions.

Along with these two omissions, we must not forget that taxing is a costly activity in itself, and generates at least two additional costs that are often passed over: the costs of administration and compliance. The existence of these costs calls for a distinction between two different notions of the Laffer curve, a gross Laffer curve, which captures the relationship of marginal rates to total tax collection, and a net Laffer curve, once administration and compliance costs have been subtracted. To the extent that administration and compliance costs are correlated with PIT marginal tax rates, so will the net Laffer curve be.

Based on the above arguments, this paper develops a full-fledged analytical model for the Laffer curve of PIT. This extended model includes consumption taxes, social security contributions, as well as administration and compliance costs. This modelling has been developed for both the individual taxpayer and the aggregate. The simulations confirm that ignoring these omitted taxes and levies has important effects on the shape of the Laffer curve. Specifically, the most critical impact occurs with the omission of consumption taxes, followed by social security contributions and, finally, by not taking into account the administration and compliance costs. If we consider all these omissions, the revenue-maximising rates drop dramatically from 62.5% to 28.20%. In other words, omitting the impact of PIT rates on the revenue collection from consumption taxes, social security contributions and administration and compliance costs overestimates the normal zone of the Laffer curve, as well as the potential revenue power of the tax system.

Appendix

As highlighted in the main text, tax compliance costs borne by an individual taxpayer has two components:

$$CC_i\left(\overline{\tau}_i\right) = C_i\left(\overline{\tau}_i\right) + T_i(y_i(C_i\left(\overline{\tau}_i\right))) \tag{A.1}$$

therefore, in the event of a change in τ_h the costs of compliance borne by an individual taxpayer will be modified in the following terms:

$$\frac{dCC_i\left(\overline{\tau}_i\right)}{d\tau_h} = \frac{dC_i\left(\overline{\tau}_i\right)}{d\tau_h} + \frac{dT_i(y_i(C_i\left(\overline{\tau}_i\right)))}{d\tau_h} \tag{A.2}$$

which, taking into account (13), the change in $C_i\left(\overline{\tau}_i\right)$ will be given by:

$$\frac{dC_i\left(\overline{\tau}_i\right)}{d\tau_h} = \begin{cases} C_0^i \cdot e^{b\cdot\overline{\tau}_i} \cdot b \cdot \frac{(a_{h+1}-a_h)}{y_i} & if \quad \tau_h < \tau_k \\ C_0^i \cdot e^{b\cdot\overline{\tau}_i} \cdot b \cdot \frac{(y_i-a_k)}{y_i} & if \quad \tau_h = \tau_k \end{cases} \tag{A.3}$$

whereas the change in $T_i(y_i(C_i\left(\overline{\tau}_i\right)))$ will be $\frac{dT_i(y_i(C_i(\overline{\tau}_i)))}{d\tau_h} = \frac{dT_i}{dy_i} \cdot \frac{dy_i}{dC_i} \cdot \frac{dC_i}{d\overline{\tau}_i} \cdot \frac{d\overline{\tau}_i}{d\tau_h}$, which after some mathematical arrangements and taking into account that $\eta_{T_i,y_i} = \frac{\tau_k}{tme} -$ where τ_k is the marginal tax rate and *tme* is the average tax rate in the PIT of the taxpayer, can be rewritten as:

$$\frac{dT_i(y_i(C_i\left(\overline{\tau}_i\right)))}{d\tau_h} = \begin{cases} \tau_k \cdot \eta_{y_i,C_i} \cdot b \cdot (a_{h+1} - a_h) & if \quad \tau_h < \tau_k \\ \tau_k \cdot \eta_{y_i,C_i} \cdot b \cdot (y_i - a_k) & if \quad \tau_h = \tau_k \end{cases} \tag{A.4}$$

It is worth noting that whereas $\frac{dC_i(\overline{\tau}_i)}{d\tau_h}$ is privately borne by the taxpayer, $\frac{dT_i(y_i(C_i(\overline{\tau}_i)))}{d\tau_h}$ is the cost to society in the form of a tax collection cut in the PIT. Therefore, of these two elements, the only relevant factor to characterise the Laffer curve is the second one. Thus, the tax revenue variation in the total population associated with the increase in compliance costs caused by $d\tau_h$ will be determined by:

$$\begin{aligned} \frac{dT\left[Y\left(C\left(\tau\right)\right)\right]}{d\tau_h} &= \sum_{N_h} \tau_h \cdot b \cdot (y_h - a_h) \cdot \eta_{y_h,C} + \sum_{N_h^+} \tau_k \cdot b \cdot (a_{h+1} - a_h) \cdot \eta_{y_k,C} \\ &= N_h \cdot \left(\overline{\tau}_{k_i}\right)_h \cdot \left(\overline{\eta}_{y_i,C_i}\right)_h \cdot b \cdot (\overline{y}_h - a_h) + N_h^+ \cdot \left(\overline{\tau}_{k_i}\right)_h^+ \cdot \left(\overline{\eta}_{y_i,C_i}\right)_h^+ \cdot b \cdot (a_{h+1} - a_h) \end{aligned}$$

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